Current Biology
Magazine

CellPress

Correspondence

Engagement with indigenous people preserves local knowledge and biodiversity alike

Elliot M. Gardner[1,2,10,*], Aida Shafreena Ahmad Puad[3], Joan T. Pereira[4], Jugah anak Tagi[5], Salang anak Nyegang[6], Postar Miun[4], Jeisin Jumian[4], Lisa Pokorny[7], and Nyree J.C. Zerega[8,9]

Indigenous peoples are important stewards of biodiversity, often living near and possessing intimate knowledge of ecosystems. As a result, species new to science may be long known to indigenous people. While the scientific endeavor has long benefitted from indigenous knowledge, it has usually not engaged with it on equal footing[1,2]. While Linnaean taxonomy offers a broad framework for global comparisons, it may lack the detailed local insights possessed by indigenous peoples. This study illustrates how meaningful engagement with indigenous knowledge — throughout the scientific process — can improve biodiversity science and promote conservation[1,2], particularly in studies of crop wild relatives, an international priority[3] for food security in the face of climate change[4]. Two species of fruit trees recognized as distinct by the Iban and Dusun peoples, but considered a single species in current Linnaean taxonomy, were confirmed as distinct taxa by molecular studies. They correspond to *Artocarpus odoratissimus* Blanco and *Artocarpus mutabilis* Becc., whose distinguishing characteristics were clarified by members of indigenous communities.

A. odoratissimus Blanco (Malay: *tarap*; Tagalog: *marang*; Figure S1) is a fruit tree related to breadfruit (*Artocarpus altilis* (Parkinson) Fosberg) and jackfruit (*Artocarpus heterophyllus* Lam.). Widely cultivated in home gardens in Borneo and the Philippines, it is common in and probably endemic to Bornean lowland rainforests[5]. A putative wild form (informally, the '*barbatus* form'), limited to Borneo[5], has somewhat smaller fruits and leaves, and often longer hairs on its buds and twigs.

The Iban people of Sarawak recognize two species. *Lumok* is the cultivated tree, with large leaves, thick twigs, large sweet fruits with thick pulp, and short hairs on the buds and young twigs. *Pingan* is a wild tree with smaller leaves, slender twigs, smaller, less-sweet fruits with thinner pulp, and often, but not always, long hairs on vegetative parts (Figure S1 and Data S1C). An ethnobotanical study recorded names reflecting their close affinity: *lumok amat* ('true *lumok*') and *lumok pingan*[6]. The Dusun of Sabah also recognize two entities: *timadang*, equivalent to *lumok*; and *tonggom-onggom*, equivalent to *pingan*.

A. odoratissimus was described by Fr. Manuel Blanco (1779–1845) from Philippine material resembling *lumok*. The Italian botanist Odoardo Beccari (1843–1920) later described *A. tarap* Becc. and *A. mutabilis* Becc. from Bornean (Sarawak) specimens without mature fruits, making them difficult to place within the Iban taxonomy. Beccari's names are considered synonymous with *A. odoratissimus*[5].

Considering both the Iban and Linnaean systems, we sequenced DNA microsatellites and used targeted capture sequencing to test these hypotheses: first, Iban *pingan* is genetically distinct from *lumok*; second, the long-haired '*barbatus* form' is genetically distinct from the typical short-haired form; third, *pingan* and *lumok* correspond to the *barbatus* and *odoratissimus* forms, respectively; and finally, *pingan* is the wild progenitor of cultivated *lumok*.

Tissue was collected in Malaysian Borneo and sampled from herbarium specimens covering the entire species range, including Beccari's types from the 1860s. Field identification was provided by Iban authors JT and SN in Sarawak and by Dusun authors PM and

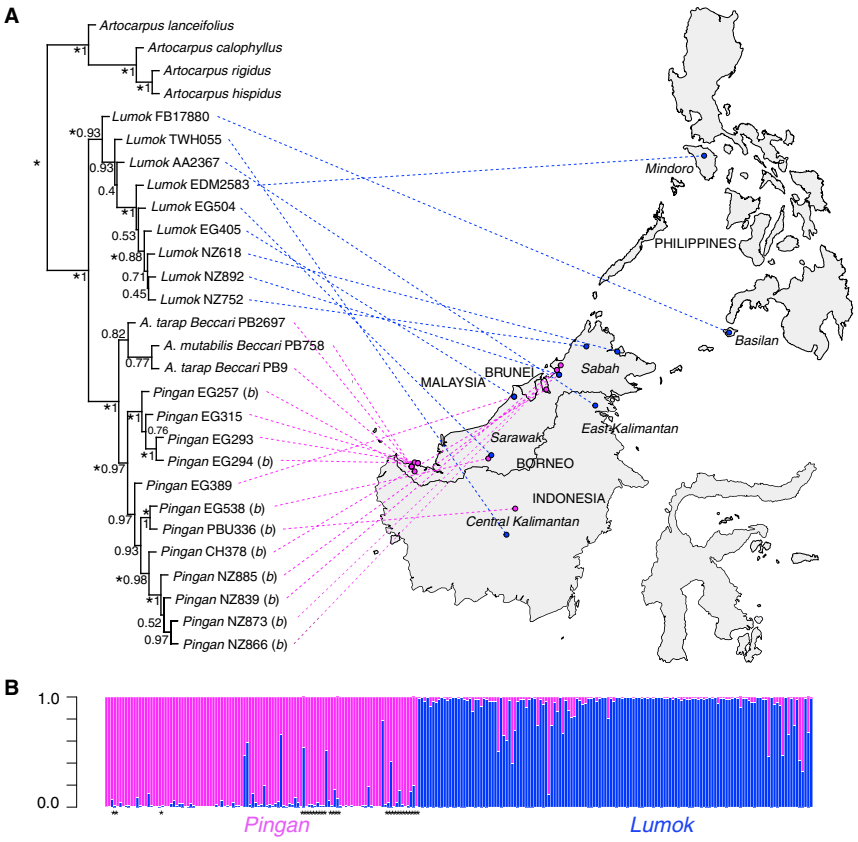

Figure 1. Phylogenomic and population genetic analyses of *Artocarpus odoratissimus*.
(A) Phylogenetic tree showing *pingan* (magenta) and *lumok* (blue) clades, with geographic origins; (*b*) denotes the *barbatus* form. Node labels are local posterior probabilities, and an asterisk denotes rejection of the polytomy hypothesis ($P < 0.05$). (B) Structure plot based on 13 SSRs under k = 2, with asterisks marking the *barbatus* form.

JJ in Sabah. A multispecies coalescent species tree using 31 samples, based on 451 nuclear genes, recovered two well-supported sister clades corresponding to *lumok* and *pingan* (Figure 1). Although in some regions (Kapit and Sabah) almost all *pingan* specimens had long hairs (*barbatus*), overall these samples comprised a subset of the *pingan* clade. Beccari's type specimens for *A. tarap* and *A. mutabilis* fell within the *pingan* clade. In a population structure analysis of 251 samples from Sabah and Sarawak, based on 13 microsatellite (SSR) loci, the most likely number of genetic clusters (K) was 2, with a clear separation between *lumok* and *pingan* (Figure 1). Genetic diversity statistics were similar between the two entities (Supplemental information). The genetic diversity of *lumok* was not a subset of that of *pingan*, and *pingan* had no private alleles with respect to *lumok*.

Only our first hypothesis was entirely supported, showing that the traditional Iban/Dusun taxonomy better reflects phylogenetic relationships than the Linnaean one. Although *barbatus* plants always correspond to *pingan*, the reverse does not apply, and fruit size and the length and shape of the fruit spines are better diagnostic characters than the length of the stipule indumentum (Figure S1 and Data S1C). These results also support *pingan* as the closest relative to *lumok*, highlighted by admixture between the two (Figure 1). Since the allelic diversity of *lumok* did not comprise a subset of that of *pingan* (Supplemental information), the latter is not supported as the wild progenitor of *lumok*. However, domesticated trees may not display the sharp reduction in wild diversity typically found in annual crops[4,7], warranting further study, focusing particularly on the occasional *lumok* found in primary forests.

Based on the genetic and morphological distinctness of *lumok* and *pingan*, they should be recognized as separate taxa, limiting *A. odoratissimus* only to *lumok*. Under current nomenclature rules, one of Beccari's names must be taken up for *pingan*. 'Tarap' commonly refers to both the cultivated and wild trees, and its correct application to the entire clade likely reflects Beccari's knowledge of Malay. As a name for *pingan* only, however, it would lead to confusion, so we propose *A. mutabilis*. We note recent calls to incorporate indigenous names into scientific nomenclature[8], for which a case might be made when the impetus for revision arises from indigenous names.

Because species conservation depends on scientific nomenclature, taxa without formal names may not be assessed for conservation. Engagement with indigenous peoples and their knowledge might spur countless studies like this one, accelerating Linnaean taxonomy by testing species concepts from multiple points-of-view and highlighting conservation needs for species that may be cryptic to professional scientists but known to indigenous peoples. The two clades described here may not have come to light without consideration of indigenous taxonomy, highlighting the importance of indigenous knowledge even when molecular phylogenetics ultimately take priority in taxonomic decisions. Increased investigation and conservation of crop wild relatives, often the subjects of substantial indigenous knowledge, is critical in the face of global change and may provide an avenue for indigenous peoples to benefit from their traditional knowledge while conserving it[3,4] — a step beyond what was possible in this study. Time is of the essence, because just as biodiversity is threatened by climate change, indigenous knowledge — itself protected under Article 8(j) of the Convention on Biological Diversity — is threatened by societal change[9]. Meaningful engagement will improve our understanding of biodiversity and promote the conservation of both biodiversity and traditional knowledge[10].

SUPPLEMENTAL INFORMATION

Supplemental information contains one figure, one data file, experimental procedures and references, and can be found with this article online at https://doi.org/10.1016/j.cub.2022.04.062.

ACKNOWLEDGMENTS

We thank the Sabah Biodiversity Centre, Chief Conservator of Forests, and Deputy Chief Conservator of Forests (Research & Development), Sabah Forestry Department (permit nos. JKI4/MBS.r000-2/2(128), JKM/MBS.1000-2/2 (175), and JKM/MBS.1000-2/2 JLD.4 (150)), and Sarawak Forest Department for permits; the Field Museum of Natural History and the Royal Botanic Gardens, Kew, for access to laboratories; Markus G., Aloysius L., Brono S., and Jegong anak Suka for assistance in the field; J. Viruel, M. Murphy, and E. James for assistance in the lab; BO, F, K, and MO herbaria for access to specimens; and Sabah Agriculture Department, Semenggoh Arboretum, Singapore Botanic Gardens, Bogor Botanical Garden, National Tropical Botanic Garden, and Govardhan Gardens for access to living collections. This study was supported by the NSF (0919119, 1501373 and 1711391), Garden Club of America, American Society of Plant Taxonomists, Botanical Society of America, Systematics Research Fund, EU-SYNTHESYS (NL-TAF-6894, GB-TAF-2437), and the Garfield Weston Foundation.

DECLARATION OF INTERESTS

The authors declare no competing interests.

REFERENCES

1. Agrawal, A. (1995). Dismantling the divide between indigenous and scientific knowledge. Dev. Change *26*, 413–439.
2. Runk, J.V. (2014). Enriching indigenous knowledge scholarship via collaborative methodologies: Beyond the high tide's few hours. Ecol. Soc. *19*, 37.
3. Castañeda-Álvarez, N.P., Khoury, C.K., Achicanoy, H.A., Bernau, V., Dempewolf. H., Eastwood, R.J., Guarino, L., Harker, R.H., Jarvis, A., Maxted, N., *et al*. (2016). Global conservation priorities for crop wild relatives. Nat. Plants *2*, 16022.
4. Viruel, J., Kantar, M.B., Gargiulo, R., Hesketh-Prichard, P., Leong, N., Cockel, C., Forest, F., Gravendeel, B., Pérez-Barrales, R., Leitch, I.J., and Wilkin, P. (2021). Crop wild phylorelatives (CWPs): Phylogenetic distance, cytogenetic compatibility and breeding system data enable estimation of crop wild relative gene pool classification. Bot. J. Linn. Soc. *195*, 1–33.
5. Berg, C.C., Corner, E.J.H., and Jarrett, F.M. (2006). Moraceae genera other than *Ficus*. Fl. Males. Ser. 1, Spermat. *17*, 1–146.
6. Christensen, H. (2002). Ethnobotany of the Iban and the Kelabit (Forest Department Sarawak, Malaysia: NEPCon, University of Aarhus), p. 384.
7. Miller, A.J., and Gross, B.L. (2011). From forest to field: Perennial fruit crop domestication. Am. J. Bot. *98*, 1389–1414.
8. Gillman, L.N., and Wright, S.D. (2020). Restoring indigenous names in taxonomy. Commun. Biol. *3*, 609.
9. Wilder, B.T., Meara, C.O., Monti, L., and Nabhan, G.P. (2016). The importance of indigenous knowledge in curbing the loss of language and biodiversity. BioScience *66*, 499–509.
10. Reyes-García, V., and Benyei, P. (2019). Indigenous knowledge for conservation. Nat. Sustain. *2*, 657–658.

[1]International Center for Tropical Botany, Institute of Environment, Florida International University, Miami, FL, USA. [2]National Tropical Botanical Garden, Kalaheo, HI, USA. [3]Plant Resource Science and Management, Faculty of Resource Science and Technology, Universiti Malaysia Sarawak (UNIMAS), Kota Samarahan (Sarawak), Malaysia. [4]Forest Research Centre, Sabah Forestry Department, Sandakan (Sabah), Malaysia. [5]Kampung Sungai Apong Baru, Kuching (Sarawak), Malaysia. [6]Rumah Salang, Tatai Ruai, Jalan Sungai Kapit Kapit (Sarawak), Malaysia. [7]Institut Botànic de Barcelona (IBB, CSIC-Ajuntament de Barcelona), Barcelona, Catalonia, Spain. [8]Northwestern University, Plant Biology and Conservation, Evanston, IL, USA. [9]Chicago Botanic Garden, Glencoe, IL, USA. [10]Lead contact.
*E-mail: egardner@fiu.edu